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Livestock research allocations in sub-Saharan Africa

Traditional and improved butter making in Ethiopia

Beef pricing policy in Zimbabwe

Kanwa—possible micronutrient fertilizer

The *ILCA Bulletin* is a quarterly publication of the International Livestock Centre for Africa. It provides an up-to-date account of aspects of the Centre's work. Contributions to the Bulletin are invited from other livestock researchers in Africa whose work is closely associated with that of ILCA. The *ILCA Bulletin* is distributed to 1500 researchers, policy makers, donors and extension agents throughout sub-Saharan Africa and elsewhere in the world.

ILCA is one of 13 international centres for agricultural research whose work is funded by the Consultative Group on International Agricultural Research (CGIAR). The 13 centres have been established by the CGIAR to provide long-term support for agricultural development in the Third World.

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Preface

More and better research is needed to resolve Africa's food crisis. The concept ‘better research’ may be variously associated with more investment, with higher scientific qualifications, or with stronger national programmes and closer cooperative ties between international research centres and national institutions. ILCA staff believe all these aspects are important; however, equally if not more important is the way available research resources are allocated between specific zones, species, and production constraints.

A study carried out by a scientist in ILCA's Systems Research Unit analyses the pattern of expenditure on agricultural research in sub-Saharan Africa, and describes the analytical methods used by international agricultural research centres in allocating their resources. The summarised paper appearing in this issue of *ILCA Bulletin* focuses, naturally, on ILCA. This centre, whose share in the total livestock research budget of sub-Saharan Africa is about 33%, may need to re-examine its research resource allocations in favour of small ruminants and the humid and subhumid zones to ensure optimum utilisation of its resources in areas likely to give the highest payoffs.

Over the past 2 years, ILCA's dairy technology team working with the Highlands Programme has been studying traditional milk processing techniques used by Ethiopian smallholders. Butter making is one of the most important processes from an economic point of view: more and better-quality butter sold will bring more cash to the farm family. To improve the efficiency of traditional butter making, ILCA's two-man dairy team have designed a simple, low-cost agitator which can be assembled inside the earthenware churn used by Ethiopian butter producers. As much as 89% of butter fat can be recovered from whole milk using this simple technological innovation, which promises to have important implications for smallholder dairying.

The third article examines the economic implications of the beef pricing policy in Zimbabwe, which is strongly influenced by government intervention. The author found that the pricing policy tends to be producer-oriented and of greater benefit to commercial producers than to smallholders. The demand for beef in Zimbabwe is price inelastic, which implies that a slight change in consumption of beef would exert pressure on the government to permit a more than proportionate change in the retail price of beef. It was also found that the domestic beef market in Zimbabwe is not greatly protected from fluctuations in the world market price of beef.

Some readers will know *kanwa* as a mineral salt supplement fed to cattle in northern Nigeria. Preliminary work by ILCA's multidisciplinary team in Kaduna, central Nigeria, suggests that it can be used equally effectively as an inorganic fertilizer to improve the fertility of ferruginous soils. The discovery was made via an analysis of *kanwa* cattle salt carried out by the team's animal scientists in an effort to determine the causes of the increased oestrous activity observed in cows during the dry season. The results of the analysis, which showed that *kanwa* contains many essential micronutrients, has excited agronomic interest in *kanwa* as a possible source of plant nutrients.

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Allocation of livestock research resources in sub-Saharan Africa*

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**This paper is a summary of a more detailed technical paper (see McIntire, 1985) which is available on request.*

Summary

EXPENDITURE ON *agricultural research in sub-Saharan Africa has generally been low, averaging US$ 366 per thousand people in 1980. Few data are available on the share of livestock research in the total agricultural research in the subregion; using publication counts, expenditure on livestock research was estimated to be between US$ 34 million and US$ 36 million. Publication counts were also used to measure research output in the subregion, taking as a basis the entire AGRIS output for the period 1975–1983. The counts suggested a clear preference by national programmes for research on cattle (about 66% of all publications) and for the humid and subhumid areas (nearly 50%). They also indicated that while animal health problems have been the main concern of national research, comparatively little has been done in the fields of basic animal science, nutrition, physiology, ecology, forage agronomy and general management.*

ILCA's share in the total livestock research in sub-Saharan Africa is about 33%. Considering the diversity of zones within the Centre's mandate, and of species and research disciplines, decisions on how to allocate the Centre's research resources effectively are extremely difficult. This paper suggests the use of economic models for the analysis of allocations by ecological zone, discipline and animal species. A comparison between ILCA's current allocations and those suggested by the analysis indicates that: a) while current allocations to research in the highlands are justified at all levels of analysis, the share of the arid and semi-arid zones is rather large, often at the expense of the humid and subhumid zones; b) social sciences are over-represented; and c) more resources should be allocated to research on sheep and goats.

Introduction

Between 1981 and 1983 the International Livestock Centre for Africa (ILCA) spent about US$ 10 million per year on livestock research. This amount represents about 7% of the total expenditure on agricultural research in sub-Saharan Africa, and as much as 33% of the expenditure on livestock research in the region. ILCA's budget grew rapidly in real terms from 1975 until 1979, but little real growth is expected to occur in the 1980s.

ILCA's research focuses on three classes of animals—large and small ruminants, and equines. ILCA has six country programmes in different ecological zones of sub-Saharan Africa which vary greatly in their human and livestock populations, in income and in economic structure, and in the capacity of the national research institutions. The Centre's research is spread among many disciplines, including animal nutrition, forage agronomy, range management, and the social sciences.

Given the magnitude of funds to be spent, decisions on the allocation of ILCA's resources among the various programmes are very important. They are also difficult, considering the diversity of zones, species, disciplines and research techniques involved. Analytical models are useful tools for generating guidelines for the allocation of research expenditures. The strength of such guidelines lies in the orderly and objective identification and quantification of the net benefits of alternative research allocation strategies.

This paper describes several possible methods of allocating research resources based on different analytical models. First, a brief review of models proposed in the literature is presented, followed by some evidence about current agricultural and livestock research in sub-Saharan Africa. Empirical tests of which variables might be important in defining the research priorities in 32 of ILCA's mandate countries are presented, as well as a comparison between ILCA's current allocation of funds and those suggested by the models.

Resource allocation models

There are two broad approaches to research resource allocation (RRA). The first is an *ex ante* approach which emphasises the composition of agricultural output: in other words, it seeks to find out to which commodities research should be directed. This approach can be termed the ‘general congruence model', and it uses different criteria to measure the importance of different commodities. Examples of such criteria are: commodity production, consumption and trade, calorie and protein supply, and size of the population producing the commodity. To these *static* measures are often added others which measure *changes* in supply, in the nutritional value of commodities, in trade and in population growth. A satisfactory allocation of resources occurs when a commodity's rank in terms of its importance within a given economy coincides with its rank in terms of the share of research expenditure.

The second approach, known as the ‘induced innovation model', is also an *ex ante* approach, but one emphasising the expansion path of output as determined by relative factor scarcities. It argues that factor scarcities have influenced research priorities in the past (Binswanger and Ruttan, 1978), and that a successful research strategy should achieve cost minimisation by saving the scarcest factor of production. In practice this means that relative factor supplies (e.g. land versus labour) should be taken into consideration when deciding which technologies should be studied. For example, land scarcity in Japan necessitated an intensive approach using biological technologies to raise agricultural output, whereas land abundance in the United States dictated an extensive approach based on mechanisation.

The congruence model confronts the difficult problem of weighting criteria. The proposed solutions to this problem are:

- The cost-benefit method, in which the costs and benefits involved are the most important criteria when selecting the research topics with the highest expected payoffs.
- The scoring method, in which scores, not money values, are assigned to research topics.
- The dominant criterion method, which focuses on an important aspect of production e.g. calorie supply (Pineiro and Moscardi, 1984).

Of the three methods outlined above the cost-benefit method is the most exacting, but it is difficult to apply in the international agricultural research centres (IARCs) because of technical problems in measuring costs, benefits and equity effects. The most commonly used method is

the dominant criterion method, perhaps because it is the simplest. However, unlike the cost-benefit and scoring methods, it does not consider the probabilities of research payoffs. The scoring method has also been used successfully in allocating research resources, even though its decision criteria are arbitrary.

Compared to the general congruence model, the induced innovation model, which also incorporates scoring, the cost-benefit and dominant criterion methods, gives only a general orientation in respect of the commodities and techniques to be studied. Its principal use has been in historical analysis of innovations rather than to provide precise guidelines for research programmes.

National agricultural research in sub-Saharan Africa

The per caput expenditures on agricultural research in sub-Saharan Africa are among the lowest in the world (Oram and Bindlish, 1981). Using the number of publications as a measure of research output, Evenson and Kislev (1975) demonstrated that the research output in the subregion has also been low. In spite of this poor record, much research work has been accomplished and is still in progress in sub-Saharan Africa. The IARCs must take this work into consideration when allocating their research resources.

Overall agricultural research expenditure

Oram and Bindlish (1981) give data on the agricultural research expenditures of 32 sub-Saharan African countries in the 1970s. Their data are reported in Table 1, which shows that in 1980 these expenditures ranged from US$ 60 to US$ 800 per thousand persons, averaging US$ 366 per thousand persons. If these figures are extrapolated to the whole subregion, the total expenditure on agricultural research in sub-Saharan Africa in 1980 was US$141.15 million.

There is a wide variation in the mean expenditures on agricultural research in sub-Saharan Africa, reflecting variations in national per caput income levels and in historical experience. Using the data in Table 1, a regression equation with a log-linear specification was estimated to determine the factors influencing expenditure on agricultural research.

Table 1. *Agricultural research expenditures and other variables for 32 sub-Saharan countries in 1980*.

Country	Population		Income/caput		Share of agriculture in GDP (%)	ARE* (US$/1000 of pop.)	Annual per caput GR* of total livestock output (%)
	Total ('000)	Density per km^2	1980 US$	Growth in '70s (%)			
Angola	7 100	5.7	470	–2.3	48	n.a*	–0.856
Benin	3 400	30.6	310	0.4	43	357.4	0.687
Burkina Faso	6 100	22.3	210	0.1	40	61.2	–0.143
Burundi	4 100	161.5	200	2.5	55	158.3	0.511
CAR	2 300	3.7	300	0.9	37	n. a.	–0.019
Cameroon	8 400	17.9	670	2.6	32	296.5	1.313
Chad	4 500	3.6	120	–1.8	57	154.7	0.432

Congo	1 600	4.7	900	0.8	12	n.a.	0.747
Ethiopia	31 100	28.2	140	1.4	51	72.3	–1.233
Ghana	11 700	50.9	420	–1.0	66	338.7	2.112
Guinea	5 400	22.0	290	0.3	37	n.a.	3.127
Ivory Coast	8 300	26.1	1 150	2.5	34	n.a.	2.961
Kenya	15 900	27.9	420	2.7	34	502.2	–0.836
Liberia	1 900	19.8	530	1.5	36	232.1	0.558
Madagascar	8 700	14.9	350	–0.5	36	420.3	–0.601
Malawi	6100	64.9	230	2.9	43	368.6	0.862
Mali	7 000	5.7	190	1.4	42	375.7	1.012
Mauritania	1 500	1.5	440	1.6	26	398.0	–1.487
Mozambique	12 100	15.8	230	–0.1	44	n.a.	–1.877
Niger	5 300	4.2	330	–1.6	33	154.5	1.684
Nigeria	84 700	93.0	1 010	4.1	20	688.6	3.143
Rwanda	5 200	208.0	200	1.5	48	55.4	–0.615
Sierra Leone	3 500	48.6	280	0.0	36	64.7	0.026
Senegal	5 700	29.5	450	–0.3	29	692.8	0.669
Somalia	3 900	6.2	155	1.0	60	86.9	–4.213
Sudan	18 700	7.9	410	–0.2	38	337.8	1.086
Tanzania	18 700	21.1	280	1.9	54	378.3	0.593
Togo	2 500	46.3	410	3.0	26	274.8	2.961
Uganda	12 600	63.0	300	–0.7	76	270.5	0.025
Zaire	28 300	12.5	220	0.2	32	163.7	–2.033
Zambia	5 800	7.8	560	0.2	15	800.7	0.482
Zimbabwe	7 400	19.1	630	0.7	12	748.0	–4.587

*ARE = agricultural research expenditures; GR = growth rates.
n.a = not available.
Sources: World Bank (1982) for columns 2,3,4 and 5; Oram and Bindlish (1981) for agricultural research expenditures. Per caput growth rates of livestock output were calculated from data in FAO (1983).

The independent variables determining research expenditure and their regression coefficients are shown in Table 2. The only variable with a significant effect on expenditure is per caput income, which alone contributes about 80% of the total variation explained by the equation. Population size, population density, the importance of livestock in the production systems and colonial experience have no statistically significant effect on investment in agricultural research. This implies that there is no reason to discriminate against large or densely populated countries in research allocation, on the grounds that their national programmes are large relative to those in smaller or less densely populated countries. Similarly, it means that colonial experience does not influence current allocation.

Table 2. *Variables determining investment in agricultural research*.

Independent Variable	Regression Coefficient	t-statistics
French colony	0.097	0.335
Income/caput	1.071	4.488***
Population	0.126	0.850
Population density	–0.122	–0.796
Share of livestock in agricultural GDP	0.019	0.100
Constant	–7.445	
Adjusted R^2	0.423	
F-statistic	4.668***	
Degrees of freedom	5, 20	

***Significant at the 1% level.
Notes: The dependent variable is agricultural research expenditure per person (in 1980 dollars) in 26 of the 32 countries shown in Table 1. The regression equation is estimated in a log-linear specification.

Factors determining research output

Evenson and Kislev (1975) proposed a function in which publication counts in 11 product categories were the measure of research output. This function suggests which factors determine demand for research and how national investment decisions are made. A similar function was specified for livestock-related publications, with the modification that the function was assumed to be a supply function.

The results of the regression equation used demonstrate that the supply of livestock research is influenced by income, but that it is not significantly related to country size (Table 3). This implies that there are no economies of scale in livestock research and that small countries do not systematically supply less research. Research output is related to the share of livestock in agricultural GDP, and even very poor, semi-arid countries with a large share are able to show some research output. These findings suggest that countries respond to economic growth (via the income elasticity of demand for livestock products), and to comparative advantage in allocating research resources.

Table 3. *Variables determining livestock research output*.

Independent variable	Regression coefficient	t-statistic
French colony	–0.077	–0.237
Income/caput	0.913	3.277***
Population	–0.181	–1.079
Share of livestock in agricultural GDP	0.466	2.772**
Constant	–5.563	
Adjusted R^2	0.288	
F-statistic	4.030**	
Degrees of freedom	4,26	

**Significant at the 5% level.
***Significant at the 1% level.
Notes: The dependent variable is the number of livestock-related publications per million persons, abstracted in AGRIS (FAO database) over the period 1975–1983. The sample included all the countries shown in Table 1. The equation is estimated in a log-linear specification.

The share of livestock research in total agricultural research

There are few data available on the share of livestock research in total agricultural research. In the absence of concrete data, the amount spent on livestock research was estimated by using two different methods. The first method was to take Evenson and Kislev's (1975) data, which showed that in 1965 total expenditure on agricultural research in sub-Saharan Africa was US$ 33.5 million. Their counts of publications showed that 25.7% of the research publications written in sub-Saharan Africa from 1948 to 1968 were from the livestock sector. Assuming that expenditures are proportional to the number of publications, US$ 8.6 million was spent on livestock research in 1965. Taking an average rate of inflation recorded for low-income countries in the 1960s and 1970s, the expenditures on livestock research in 1980 were US$ 34.3 million.

The second method is based on the data for 26 countries collected by Oram and Bindlish (1981) and reported in Table 1. Multiplying the data by the fraction of livestock-related publications gives a value for 1980 of US$ 36.3 million, a figure comparable to the US$ 34.3 million extrapolated from the Evenson and Kislev results.

It is pointless to argue here about which method is the better one; both of them establish a range of expenditures and a standard against which ILCA's contribution to research in the subregion can be compared.

The disciplines, ecological zones and animal species covered by national research programmes

A study of the records of national institutions can help the IARCs to allocate their resources effectively. The usual measures of these records are expenditures on agricultural research and the numbers of scientists employed. The defects of these measures are that they measure input, not output, and that they are influenced by different purchasing power and educational levels[1]. Furthermore, because of their form the data usually do not include information on allocations by discipline, ecological zone, and the crop or animal studied.

1. For example, PhD degrees are uncommon in francophone Africa; the responsibilities of a francophone *ingenieur agronome* are, however, often equal to those of an anglophone PhD holder.

As an alternative to expenditure or man-year data, publication counts have been suggested (Evenson and Kislev, 1975) as a measure of research output. Unlike expenditures, this measure is not affected by the exchange rate, and unlike numbers of scientists, it is independent of educational level comparisons. Publication counts also have some claim to objectivity: an appearance in a refereed journal establishes, to some extent at least, the quality of the research reported.

Despite these points in favour of publication counts, the method is not perfect. For example, it does not take into account the size of publications: Is a long paper worth more than a short one? Is a project described in three papers worth three times as much as another described in one, long paper? Moreover, some journals have higher standards than others, a factor which, again, is not reflected in this method.

Nonetheless, publication counts were used to determine the representation of species, disciplines and ecological zones in national research programmes, taking as a basis the AGRIS output for the period 1975–1983. In general, publications were included in the counts if they appeared in refereed journals or in other reviewed sources such as published conference proceedings. Training documents, mission reports and research proposals were excluded. Annual reports of research stations were also excluded, because they were apparently undercounted, and because they often contained work published elsewhere or irrelevant material such as personnel lists and budgets. Publications from international institutes were not included in the counts because they are not functions of national research investment. Obvious duplications (for example, a paper appearing both in a journal and in conference proceedings) were excluded.

Table 4 shows that roughly two thirds of the publications which could be clearly assigned to a particular animal dealt with cattle. This is comparable to the value of cattle, which showed them producing about two thirds of the total output of livestock products in the subregion (see Table 7).

Table 4. *Results of a search on the AGRIS database for livestock research publications published in sub-Saharan Africa during the period 1975–1983*.

Category	% share of publications
Animal species (n = 844)	
Cattle	51.1
Sheep and goats	19.0
Camels	3.1
Cattle, sheep and goats	4.1
Not specified	22.7
Topic (n = 844)	
Breeding	4.9
Ecology, pastures, forages	12.1
Health	40.4
Management and social sciences	14.0
Meat, milk, wool	3.2
Nutrition, supplementation	8.6
Physiology	4.6
Trypanosomiasis	12.2
Zone (n = 476)	
Arid, semi-arid	43.3
Subhumid	28.2
Humid	19.1
Highland	9.5

Animal health and the separate category of trypanosomiasis[2] accounted for slightly more than 50% of the publications, while ecology, pasture and forages, and general management accounted for about 25%. Surprisingly, only a small proportion of publications dealt with basic animal science: animal breeding, physiology and nutrition accounted for less than 20% of all counts. While one can argue about the character (basic or applied) of such categories as health and management, the abstracts strongly suggested that much of this work is purely descriptive.

2. Trypanosomiasis included trypanotolerance, which accounted for less than 5% of the publications in this category.

Research sites were mentioned in about 56% of the reviewed publications, the emphasis in national programmes being clearly on the higher-potential areas. For example, while the subhumid and humid areas contain only 25% of the total ruminant livestock population in sub-Saharan Africa, nearly 50% of the reviewed publications originated in those areas. This is partly due to the great number of publications dealing with animal health, particularly trypanosomiasis.

Congruence analysis of resource allocation

Congruence analysis has been used to determine ILCA's allocations of research resources by region, ecological zone and animal. Congruence analysis is a technique measuring the fit between a given and a proposed allocation of research resources. For example, the shares of research by country can be compared to the share of each country's livestock in Africa's total, or the shares by animal species can be compared to the total value produced by that species.

The major difficulty in defining appropriate allocations is the weighting of different criteria. While the dominant criterion approach may seem to be the most appropriate in Africa, factor analysis appears to be a more practical technique as it augments the use of a single criterion and reduces the complexity of many.

Factor analysis eliminates redundant information by showing which variables are highly correlated. For example, if total population and rural population are highly correlated, then it is unnecessary to use both as criteria. However, any choice between two variables based on bivariate correlation is arbitrary because their relations to other variables are unknown. Factor analysis avoids this by determining the correlations among variables and using these correlations to indicate which variables contribute most to the total variation. For example, if income growth is uniformly low in a sample of countries, it contributes little to the total variation, and hence is not valuable in distinguishing among countries. If, however, income growth differs widely in the sample, then it can be used to distinguish among countries.

Of the original 20 variables (McIntire, 1985), four variables can be used to describe much of what is important about African livestock. These variables are animal protein per caput, per caput income, total population and population density. Protein from animal sources is a proxy for other measures of the livestock contribution to the national economy that are harder to measure, or which may not contribute directly to human welfare, such as the share of livestock in GDP. Per caput income measures the average welfare level and is thus a proxy for national research capacity because income is highly correlated with agricultural research expenditures per person. Total population represents the potential number of beneficiaries, and includes both the producers and consumers of livestock products. Population density is an indicator of the pressure on resources. It is negatively correlated with the share of livestock in agricultural GDP and with protein intake, but it is positively correlated with livestock density. This implies that areas with high population densities would benefit much from livestock research because of the high pressure on resources, and because of possible increases in the consumption of animal protein.

In order to determine resource allocations by region, by ecological zone and by animal, a set of weights was constructed from the factor analysis (FA), based on the four variables described above. The weights were constructed by taking the lowest or highest value for a given variable, setting it equal to 100, and calculating country values as proportions of 100 (von Oppen and Ryan, 1981). For example, Chad had the lowest per caput income (US$ 120) in sub-Saharan Africa and received a value of 100. Nigeria, with a per caput income of US$ 1010, received a value of 11.9. On the other hand, Nigeria had the highest population (84.7 million people) in the subregion and received a weight of 100; Chad, with a population of 4.5 million, received a weight of 5.3.

Allocation by region

The weights were summed across variables for each country and the sum was divided by the total of all weights for all countries. The resulting quotient, expressed in percent, is the share each country would have in the total allocation of research resources. The country shares were then summed for each region, and are shown in Table 5 as the unweighted shares. As a comparison, allocations based on a single dominant criterion—tropical livestock units (TLU)—were also included in the table.

Table 5. *Resource allocations by region in sub-Saharan Africa based on factor analysis and on TLU numbers*.

Region	Unweighted shares (%)	Shares of total TLU (%)
	FA	
Central	10.1	3.3
East	33.0	60.2
Southern	16.7	10.0
Western	40.1	26.5

TLU = 250 kg of liveweight.

If allocations were based solely on TLU numbers per region, the share of East Africa should be roughly double that suggested by the factor analysis, while the shares of West and southern Africa would be reduced by about one third, and that of central Africa would be negligible. This implies that other criteria (e.g. number of people, income and protein consumption) need to be considered in the allocation process, or that reasons for not considering them should be clearly specified.

Allocation by ecological zone

As productivity is to some extent determined by the ecological environment, not by political boundaries, it is preferable to allocate resources by ecological zones rather than by regions. The regional allocations can be extended to ecological zones by a slight modification, assuming that variables do not vary systematically across zones within a country. For example, it is assumed that per caput income in both the humid and semi-arid zones of Nigeria is US$ 1010.

Zonal weights were constructed by using four variables from the factor analysis. First, each country's share in the four variables was summed across the variables to get a national score. The national scores were then weighted by the countries' shares in each of the four major ecological zones. The values were summed up, giving the zonal shares shown in Table 6.

Table 6. *Resource allocations by ecological zone in sub-Saharan Africa as suggested by factor analysis and TLU numbers*.

Ecological zone	% of allocation	
	FA	TLU/zone
Arid/semi-arid	30.8	57.6
Subhumid	27.8	19.2
Humid	22.0	5.2
Highlands	20.1	17.2

It is obvious from the results presented in Table 6 that there is a major difference in the theoretical allocations suggested by the two methods, the reason being that while some zones have few TLUs, a low consumption of animal protein and, in some cases, low incomes, they are given high scores on variables which an allocation based only on TLU ignores.

Allocation by animal species

The allocation of research resources by animal species takes into account the total value of domestic livestock produce and the shares contributed by different animal classes.

The contributions of the two most important classes, cattle and small ruminants, were estimated by constructing value indices for meat and milk produced in 32 sub-Saharan African countries. A total meat value per country was calculated by multiplying the slaughter weights of cattle, sheep and goats by the average 1976–1980 international price of beef (US$ 1639/t). The milk value per country was obtained by multiplying the quantity of milk produced by the average 1977–1980 international price of milk (US$ 377/t). Adding up the country values of meat and milk gave the respective totals for the 32 countries (Table 7).

Table 7. *Values of livestock products produced in 32 sub-Saharan African countries in 1980*.

Product	Values (million US$)	% of total value
Cattle		
Meat	2 715	41.2
Milk	1 814	27.5
Sheep and goats		
Meat	1 314	19.9
Milk	746	11.3
	6 589	

Table 7 shows that cattle contribute about 69% of the value of livestock output in 32 countries, which implies that a similar percentage of research resources should be allocated to them. This figure compares well with the result (about 66%) obtained when publication counts were used to measure output. However, allocations on the basis of the contributions of different species to total livestock output can be biased if international and subregional prices differ systematically

from one another, or if some important products, such as manure and draught power, have been excluded from the analysis.

Current and suggested allocations at ILCA

The appropriateness of ILCA's current allocation of research resources can be assessed by calculating the numbers and costs of ILCA scientists by zone and comparing them to the allocations suggested by congruence analysis. Tables 8 and 9 show the numbers of scientists per discipline and the costs per zone as proposed in ILCA's 1985 budget (ILCA, 1984), and their respective percentages of the totals.

Table 8. *Allocation of ILCA's research resources by discipline, 1985*.

Discipline	No. of scientists	% of total
Agronomy	12	15.8
Animal science	24	31.6
Social sciences	19	25.0
Ecology	13	17.1
Management	3	3.9
Nutrition	5	6.6
Total	76	

Table 9. *Allocation of ILCA's research resources by zone, 1985.*

Zone	Total cost (US$ '000)	% of total cost
Arid/semi-arid	3 405	47.1
Subhumid	1 419	19.6
Humid	1 058	14.6
Highlands	1 353	18.7
Total	7 234	

Note: Administration and other support services are not included.

Several conclusions can be drawn from the figures presented in these tables. First, ILCA's current allocation of research resources is congruent with the distribution of tropical livestock units in sub-Saharan Africa. Second, social sciences seem to be over-represented. Third, if ecology and agronomy were grouped into one general category, the ‘environment' category, the sum of their respective shares would be only about 33%. This seems low in general and is certainly rather low when compared to social sciences. Fourth, arid and semi-arid zones are allocated far more of ILCA's resources than the subhumid zone. Considering that the subhumid zone has a greater potential than the arid and semi-arid zones, this is hard to justify, except when stock numbers only are taken into account. Fifth, the allocation to the humid zone appears to be rather low. However, since a major problem in this zone is trypanosomiasis, to which

ILRAD already devotes much of its effort, this may be justified. Sixth, if scientists in the central scientific units at headquarters (particularly nutritionists and forage agronomists) spend most of their time analysing samples from the highlands, then the time they were supposed to devote to other zones is overestimated. In terms of Table 9, the percentage share of the highlands in the total allocation would increase and those of the other zones would decrease.

Conclusions

Implications for allocations by zone

ILCA's current allocations by zone are congruent with numbers of TLUs. If such criteria as income, animal protein consumption and total human population were to be taken into account, the respective zonal shares would shift in favour of the more humid zones of sub-Saharan Africa. This shift would be justifiable on welfare grounds, since the people expected to benefit from more research in these zones have low incomes and low animal protein consumption.

Estimates of the possible gains from research suggest that allocations made to the arid and semi-arid zones are rather large, often at the expense of the subhumid zone. This conclusion is conservative, in that it does not consider the potential gains obtainable in the humid and subhumid zones from changes in the stratification of the cattle industry. If these zones have a greater scope for finishing cattle than the arid and semi-arid zones, then some of the apparent return from the latter—derived from their large livestock populations—is properly attributable to the subhumid and humid zones. Furthermore, it is sometimes argued that cattle are significantly undercounted in the subhumid zone; if this is true, greater research effort in this zone would certainly be justified.

ILCA's allocations to the highlands are more or less congruent at most levels of analysis, and this justifies a continuing major effort there. However, if the applicability of research findings from the highlands to other zones is low, then any expansion of the work in the highlands must be carefully examined. This applies especially to basic work in physiology and nutrition.

Implications for allocations by discipline

The readily observable feature of ILCA's recent research allocations is the preponderance of social scientists, not only with respect to other disciplines within the centre but also to the number of social scientists working in two other, comparable CGIAR centres[3]. This preponderance may be due to the historical belief that many of the technical answers to the problems of African livestock production were known., and that ‘socio-economic issues’ constituted the main constraint to increased output. It seems safe to say that this belief has been discredited. The contribution of social sciences to livestock research and, consequently, their share in ILCA's budget, should therefore be re-examined.

3. In 1983, 5.3% of IITA's scientists were social scientists (IITA, 1984), and the comparable share for ICRISAT in 1982 was 6.2% (ICRISAT, 1983).

A separate review based on publication counts indicated that most of the economic work undertaken in the African livestock sector was exclusively descriptive, and that very little quantitative work was done on constraint evaluation. An emphasis on descriptive research may

be justified in universities, but it is definitely inconsistent with the mandate of ILCA, as well as with the practices of other IARCs.

Implications for allocations by animal species

The historical emphasis on cattle is obviously justified. However, it does seem to have been too strong, especially *vis-à-vis* small ruminants, whose contribution to livestock production in the subregion has consistently been undervalued. Small ruminant production requires smaller initial investment, presents less risks and offers faster returns, thus ensuring more equitable distribution of incomes. These are strong arguments for allocating more resources in the future to research on sheep and goats.

Decisions on the location of animal-specific research within zones are more difficult to make. However, if basic work (for example in animal physiology) is transferable between species in the same zone, then centralisation of such work would be advisable on the grounds of possible economies of scale.

ILCA's relation to national research programmes

National research programmes in sub-Saharan Africa are underfunded. ILCA's share of the total livestock research in the subregion is high (about 33%) compared with analogous shares of other international centres. It is not only unlikely that ILCA's involvement will be increased; it is also undesirable that it should be. Since strong national programmes are essential for effective technology transfer, it follows that more of the research work needs to be done at the national level while keeping ILCA's total allocation of research resources constant or, at best, raising only the shares of disciplines insufficiently covered by national programmes.

Although national programmes have devoted much effort to solving animal health problems, basic animal science has generally received little attention. This allocation of resources may have been justified in the past, since disease has obviously been a major constraint to livestock production in the subregion. The paucity of national work on other major problems—such as nutrition, physiology and forage agronomy—may be related to a lack of basic research in these areas, due probably to inadequate funding. Without more economic growth, national programmes will continue to be unable to fund expensive basic work.

Another striking feature of national research is the concentration on higher-potential areas and on cattle. These preferences can be explained by the need to use limited resources in areas likely to give the highest expected returns, and the greater share of cattle production in exports. The comparative advantage of national programmes in better areas suggests that the base of knowledge is widest there, implying in turn that adaptive research, carried out by small ILCA teams in collaboration with national programmes, is likely to have the highest probability of success in these areas. The relative scarcity of national research in the drier areas, and the more difficult problems these areas present, underscore the need for a continued, concentrated effort on the part of ILCA in the arid and semi-arid areas. The need to concentrate efforts in these zones—in the sense of focusing the effort on one site—should not be confused with the need to reduce the allocation to these zones relative to that made to areas with higher potential.

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Traditional butter making in Ethiopia and possible improvements

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Summary

FEW FARMERS IN *the Ethiopian highlands have a ready outlet for their surplus liquid milk; the majority can only market products with greater storage stability. A survey of traditional butter making in the Ethiopian highlands has revealed that both the equipment and the methods currently used are inefficient. Traditional churning is time consuming and labour intensive, and results in considerable losses of fat in the buttermilk.*

Experiments carried out with a traditional clay pot churn fitted with an internal agitator indicate that as much as 90% of the fat can be recovered from whole milk. Internal agitation also reduces the time needed for churning, making the process more efficient and reducing labour requirements.

Separating the cream from the milk by surface skimming or by centrifugal separation improves fat recovery considerably, but both methods have certain drawbacks in respect to smallholder dairying. Gravitational separation is not feasible with the small quantities of milk retained daily by producers for processing, and the machinery used for centrifugal separation is too costly for the individual farmer to purchase. However, centrifugal separation could be economic if a number of farmers pooled their milk to accumulate an adequate volume. Cream from 100 litres of milk could be processed daily into butter by combining centrifugal separation with the improved earthenware churn.

Introduction

The typical Ethiopian highland farm produces a small surplus of milk for sale. Farmers close to main roads within 120 km of Addis Ababa have no marketing problems: they can sell their milk directly to consumers or to traders, as well as to the Addis Ababa dairy industry through an established milk collection system. Elsewhere in Ethiopia, farmers near towns generally have a ready outlet for their liquid milk. However, most farmers live a long way from major roads and have poor access to such markets, and these farmers have to rely on products which have greater storage stability than fresh milk.

Most of the milk produced by these isolated farmers is consumed by their families as fresh or coagulated milk. However, members of the Ethiopian Coptic Church abstain from milk and animal products for approximately 150 days per year. Hence there are periods when nearly all the milk produced must be converted into butter and cottage cheese, which have poor storage stability and are usually sold in markets nearby.

Since animals and their products contribute about 30% of the farm family's gross cash income (Gryseels and Anderson, 1984), improvements in milk processing could provide a substantial boost to agricultural development in the highlands. But before improvements can be made, it is

essential that the traditional dairy technologies are understood in order to identify areas in which innovations can be effectively introduced. It is also important to define the way in which the existing technology fits into the farming system and the local community, lest a new technology should prove to be incompatible with current practices and the demands of the local market.

Fat recovery is an important factor determining the efficiency and profitability of smallholder dairy enterprises in the Ethiopian highlands. At present nearly 50% of traditional processors recover between 50 and 67% of the butterfat from whole milk, and a further 12.5% of producers recover less than 50%. The retail price for butter fluctuates between EB 10 and 23 per kg (US$ 5 and 11.5 per kg), depending on its quality and on market demand, which is high at Easter and during other feasts but low during the fasting periods prescribed by the Coptic Church. No premium is paid for any fat remaining in the main byproduct of butter making—the local cottage cheese called *ayib.* When the cheese is sold or, in the extreme case, wasted, poor fat recovery in butter can lead to considerable loss of income; however, when it is consumed at home, the fat remaining in *ayib* is a valuable addition to the diet, contributing in this way to the income of smallholders. A 10% increase in butterfat recovery could be expected to increase income by about EB 5 (US$ 2.5) per 100 litres of whole milk processed.

ILCA's dairy technology team has studied the traditional method of butter making to determine the efficiency of the process and the quality of butter produced. This paper summarises the results of the study and reports on initial experiments carried out to devise improved methods of butter making.

Dairying practices were monitored on 25 farms in seven locations in the Ethiopian highlands, and on 11 farms in the Debre Berhan area. Most of the farms were traditional smallholdings. Producers' cooperatives and farmers with crossbred cows who are collaborating in ILCA's research were also included. The enterprises surveyed were in locations ranging in altitude from 1700 to 3060 m a.s.l. Dairy production from crossbred (Boran × Friesian) as well as local Zebu cows was documented in the survey.

The quality of butter made and the type of equipment used were noted, and the quantities of milk processed were recorded. Churning by hand was studied in detail because it is not only the most important form of processing carried out, but also an activity in which there is likely to be scope for improvement. Parameters such as processing time, temperature., acidity and product yield were measured in order to gauge the efficiency of current churning practices.

Milk fat analysis of both the whole milk and buttermilk was done by the Gerber method on two samples of each (Foley et al, 1976). If a difference of more than 0.1% was observed, the analysis was repeated. Milk acidity was measured by titrating 10 ml of milk to a phenolpthalein end-point using N/9 sodium hydroxide. Churning time was the time interval between the start of churning and the visible formation of butter grains. Milk temperature was recorded using a thermometer.

Traditional butter making

Traditional Ethiopian butter *(kibe)* is always made from soured milk (*irgo*); cream is not used. The sour milk is placed in a clay churn or a bottle gourd (calabash). Churns are usually spherical, with a neck 10 cm in diameter at the narrowest point and a vent 0.5 cm in diameter near the neck. The churn may have previously been smoked with *Olea africana.* Besides imparting a distinct flavour to the butter, this practice has a bacteriostatic effect, and may reduce

processing time by heating the churn. After filling, the churn is stoppered with a plug, a false banana leaf, or a piece of skin or leather stretched over the mouth and securely tied (Figure 1). The churn is then agitated. Four different methods of agitation were observed in the survey:

- The churn is placed on the floor, on a soft pad of material such as sheep skin or straw, tilted at an angle of 75° to the horizontal, and rocked back and forth (Figure; 2).
- The churn is hung on a tripod or door post and swung to and fro (Figure 3).
- The churn is rocked on the lap.
- The churn is shaken with both hands.

Figure 1. *Traditional earthenware churn. Background: Churn stoppered with a piece of skin.*

Figure 2. *Churning on the ground—the most common method observed.*

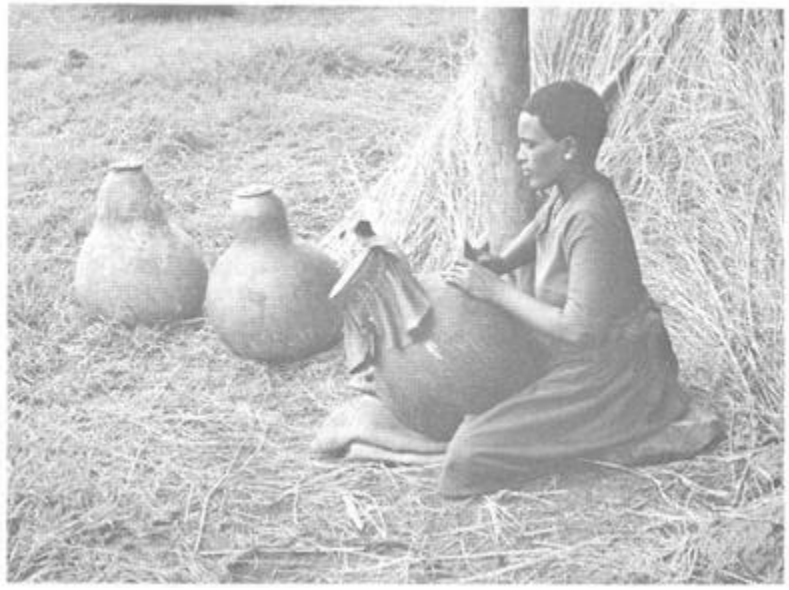


Figure 3. *Making butter in a bottle gourd hung from a tripod.*

The latter three methods are used only with bottle gourds, and only when fewer than 10 litres of milk are churned.

The break point, i.e. the point when butter starts to form, can be detected by a change in the sound of the milk. Many dairy women also insert a straw into the churn through the vent: if there are small butter grains adhering to the surface of the straw, the break point has been reached.

After churning for a few minutes more the straw is again inserted through the vent. If the straw is clean this indicates that the butter granules have coalesced into larger grains. The churn is then rotated on its base; the grains which collect in the centre form lumps of butter which are skimmed off. The butter is then kneaded in cold water and washed to remove visible residual buttermilk.

Butter quality

Butter is sold in rural markets and at the central, public butter market in Addis Ababa. The samples of fresh butter taken from these markets exhibited texture defects, particularly loose moisture, and a distinct smoky flavour. In rural markets the butter is sold by volume, the weight of which can vary considerably. In the Addis Ababa market butter is sold by weight. Samples of butter were analysed to determine the contents of moisture and free fatty acids (index of rancidity), and the serum pH (index of milk acidity). The serum pH of the samples ranged from 4.3 to 4.7, indicating that all the butter analysed was produced from sour milk. The moisture content varied from 2 to 43%, most samples having less than 16% moisture. The content of free fatty acids in the butter sold in rural markets varied from 0.23 to 1.20%. Older butter sold in the Addis Ababa market had free fatty acids content of as high as 23%.

For comparison, a study was also made of the quality of butter made on farms around Debre Zeit that use traditional methods and produce butter on a regular basis over a number of months. The moisture content of the butter varied between 13 and 30% and content of free fatty acids was between 0.07 and 3.32%. On some farms there was little variation in the composition of butter produced in different months.

Churning efficiency

The data presented in Table 1 reveal that churning time was long on most of the 25 farms studied, while milk acidity was high on nearly all of them. Churns were usually either over- or underfilled. In addition, commercial losses were considerable since much of the fat in the milk was not converted into butter—the product with the highest market value. The magnitude of these losses is indicated by the price differential between butter (average farm gate price of EB 9/kg or US$ 4.50/kg) and cottage cheese (EB 1/kg or US$ 0.50/kg). The butter produced also exhibited body defects in that it often had loose moisture and open texture.

Table 1. *Churning efficiencies observed on 25 farms in the Ethiopian highlands, 1983–1984*.

Farm	Quantity of milk (litres)	Acidity (%)	Fat in whole milk (%)	Milk temp. (°C)	Churning time (min.)	Fat in butter-milk (%)	Fat recovery[a] (%)
1	4	0.92	4.2	19	18	1.0	76
2	4	0.90	5.5	17	39	1.0	81
3	5	1.05	5.2	17	88	1.0	80
4	3	1.15	5.3	19	34	1.1	79
5	17	1.04	4.0	17	219	0.5	87
6	10	0.70	4.3	23	52	0.9	56
7	17	1.03	3.5	19	95	0.7	80

8	2	0.75	4.3	22	35	0.6	86
9	12	0.88	3.4	19	72	0.3	91
10	9	0.90	4.9	12	63	0.6	87
11	18	1.03	4.5	18	98	1.6	64
12	17	0.43	3.6	19	303	0.3	91
13	5	0.83	3.2	17	89	2.0	37
14	5	0.88	4.1	17	53	1.5	63
15	7	0.93	2.3	18	114	0.9	60
16	3	0.30	6.0	17	67	1.2	80
17	3	0.78	4.4	19	40	2.0	60
18	19	1.00	4.7	17	111	1.8	62
19	17	1.00	4.7	17	96	1.4	70
20	19	1.00	4.7	17	146	0.8	83
21	7	0.86	4.7	19	39	1.0	78
22	7	0.90	4.5	25	46	0.7	84
23	11	0.61	4.5	16	145	0.3	93
24	17	1.00	5.0	16	105	1.4	72
25	5	1.02	5.2	20	75	1.2	76
Average	10	0.88	4.4	18	90	1.0	75
SE	5.1	0.2	0.8	2.5	63	0.5	13

[a] $\text{Fat recovery} = \dfrac{fat\,in\ whole\ milk - fat\,in\ buttermilk}{fat\,in\ whole\ milk} \times 100$

Additional field observations were made to study the existing churning practices of members of the Bekelo Service Cooperative in the Debre Berhan area, who expressed interest in cooperative dairy processing. These data, which were collected during a baseline study of 11 farms, also indicate considerable losses of butterfat and long churning times (Table 2).

Table 2. *Churning efficiencies obtained with the traditional clay pot churn on 11 farms in the Debre Berhan area, 1984*.

Farm	Milk quantity (litres)	Milk acidity (%)	Fat in whole milk (%)	Milk temp. (°C)	Churning time (min.)	Fat in buttermilk (%)	Fat recovery (%)
1	7	0.73	4.2	13	150	1.0	76
2	6	0.95	5.0	15	170	2.1	58
3	11	0.89	6.5	16	150	0.6	90
4	9	0.72	3.9	18	120	0.7	82
5	7	0.79	6.0	19	150	1.6	70
6	4	0.80	4.5	18	60	0.8	82

7	13	0.74	4.1	19	105	2.0	51
8	3	0.80	3.8	18	150	0.7	82
9	11	1.15	5.5	20	55	0.6	89
10	7	0.84	4.8	15	105	0.5	90
11	10	1.10	5.1	13	270	1.2	76
Average	8	0.86	4.9	17	139	1.1	77
SE	3.1	0.15	0.87	2.45	58.6	0.57	12.8

Both surveys indicated that, in addition to being labour-intensive, traditional churning methods are inadequate to cope with a substantial increase in milk supply. Alternative methods to reduce churning time and increase the recovery of fat in churning were therefore investigated.

Performance of three types of churn

The performance of the clay pot churn was compared with those of a locally made and an imported wooden churn. The locally made churn is static, cylindrical, has a hand-operated revolving beater and a capacity of 30 litres. The imported wooden churn is also cylindrical but is fitted with fixed beaters and is rotated by hand. Its capacity is 31 litres. The traditional earthenware churn has a capacity of 24 litres, and the churning action is achieved by rocking the churn back and forth.

The milk used in the experiments was collected from crossbred Zebu x Friesian cows at the barn at ILCA headquarters. The milk was accumulated over a number of days and allowed to sour naturally before being bulked and mixed to ensure uniformity. Each churn was filled to half of its capacity with portions of the bulked, soured whole milk. The milk acidity was between 0.8 and 0.9% and the churning temperature ranged from 17 to 23°C. Churning time, fat content of the buttermilk and moisture of the final product were recorded using standard techniques (AOAC,1980). The churning time was the time taken to first formation of butter grains.

The trials were conducted with the three types of churn over a 3-month period in 1984. Table 3 summarises the results of these trials, presenting average figures for churning time (CT) and the fat content (FC) of the buttermilk.

Table 3. *Average churning time (CT, minutes) and fat content of buttermilk (FC, %) obtained with three types of churn, 10 replicates, 1984*.

	Local wooden churn		Imported wooden churn		Traditional clay churn	
	CT	FC	CT	FC	CT	FC
Range	45–64	0.5–1.4	35–55	0.5–1.2	96–224	0.5–1.4
Average	56	0.86	44	0.9	134	0.9
SE	6.51	0.36	7.76	0.25	43.1	0.296

The traditional clay pot churn is capable of churning whole milk as exhaustively as both the wooden churns, but the time taken for butter to form is considerably longer. Both wooden churns speeded up butter making and required less labour than the traditional earthenware churn, presumably because they had effective agitation systems. Unfortunately, they are too

expensive for individual smallholders: even the locally made wooden churn costs about EB 200 (US$ 100), while the price of the imported one is around EB 500 (US$ 250). Moreover, as wooden churns are not normally produced commercially in Ethiopia, smallholders would have to use imported churns, which are difficult to obtain.

Improvements to the traditional technology

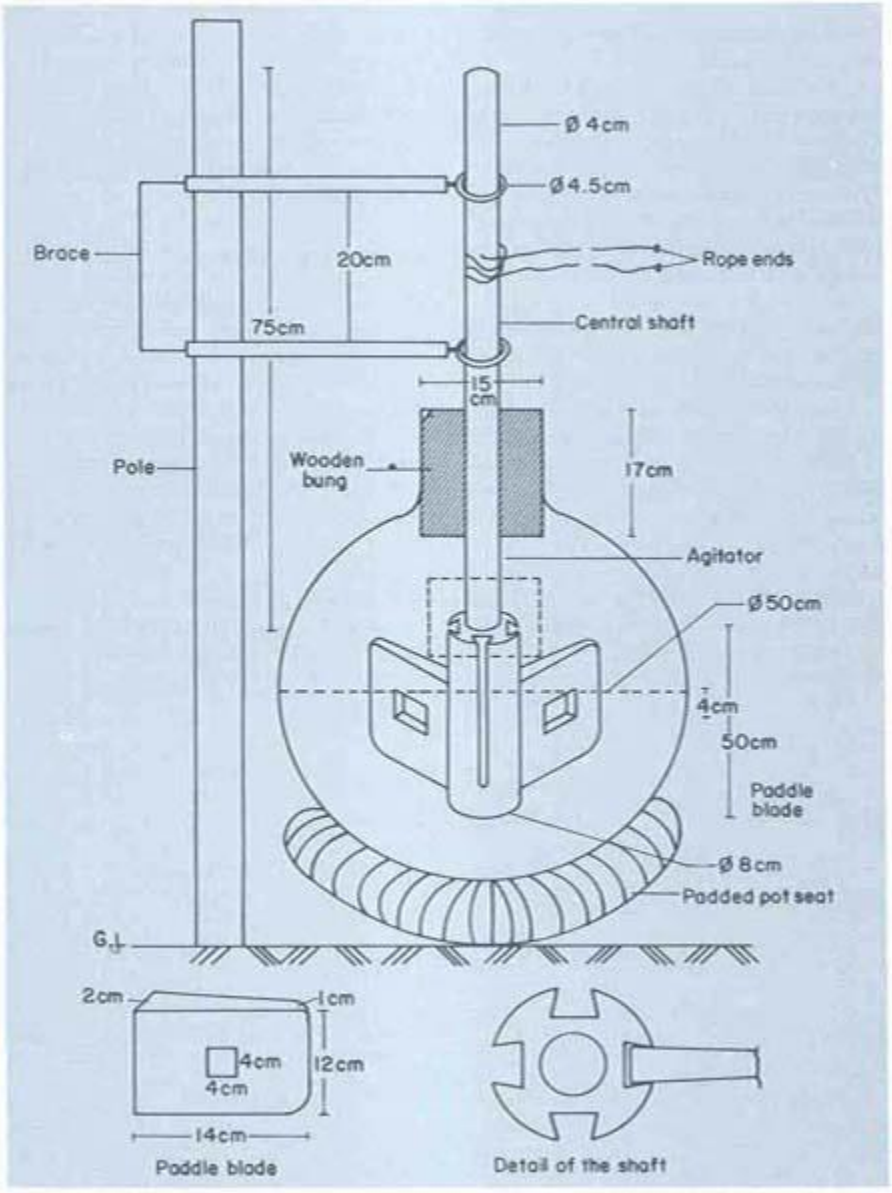
Two approaches could be used to improve the traditional technology. The first is to fit the traditional earthenware churn with an internal agitator. The second, which could be complementary to the first, would be to separate the cream from the whole milk before churning, thereby concentrating the fat in the cream fraction. This would give greater recovery of fat as butter, reduce labour input and increase the output from the churn. However, the small volumes of milk handled by most smallholders would make the use of a separator uneconomical. The performance of an earthenware churn fitted with an agitator churning sour whole milk was therefore investigated.

Internal agitation

The traditional churn has a minimum neck diameter of about 10 cm and an internal body diameter of up to 40 cm. The installation of an agitator in this churn presented a problem in that, when assembled, large paddle blades would not pass through the narrow neck, and paddle blades which were small enough to fit through the neck proved ineffective.

A simple, low-cost agitator that could be assembled inside the churn was designed and constructed by ILCA. It consists of a central shaft, paddle blades, and restraining shafts which fix the agitator in position. The paddle blades are fitted on the central shaft *in situ*. The agitator is driven by pulling on a rope wound around the main shaft of the agitator (Figure 4).

Figure 4. *Traditional earthenware churn fitted with a wooden agitator.*



Note: For smaller churns the dimensions of the paddle blades and shaft will have to be reduced proportionally.

In 1984 and 1985, 16 trials were performed at ILCA's Debre Berhan field station using locally purchased churns fitted with paddle blades made of soft wood. The milk for churning was collected from the station's crossbred cows and allowed to develop acidity naturally in a clay pot which was filled to half its volumetric capacity.

The data in Table 4 suggest that the simple internal agitation system can considerably reduce churning time, in addition to increasing the quantity of butterfat recovered. Studies are now being made on the effect of milk acidity, fat content, holding time and churning temperature on the exhaustiveness and duration of churning.

Table 4. *Churning efficiency of a traditional clay pot churn fitted with an internal agitator*[a].

	Milk acidity (%)	Milk temperature (°C)	Churning time (min.)	Fat content		
				whole milk (%)	Buttermilk (%)	Fat recovery (%)
Range	0.72–0.92	14–19	30–100	3.7–5.2	0.2–0.7	80–95
Average	0.83	16	61	4.3	0.4	90
SE	0.05	1.44	19.21	0.47	0.14	3.86

[a] Sixteen trials with a churn of 32 litres volumetric capacity; 16 litres of whole milk were used in each trial.

Cream separation

Full recovery of butterfat from whole milk is not possible, as the coalescence of fat globules is hindered by a large volume of intervening liquid (Hunziker, 1927). However, if cream is separated from the milk, a higher concentration of fat globules is obtained and, consequently, less fat is lost in the buttermilk. Cream can be separated from the milk by gravity or by centrifugation. These two basic methods are described below.

Gravitational separation is the process whereby milk is kept still in a cool place for a day or more and cream that has risen to the surface is skimmed off. Two techniques of gravitational separation can be used—shallow- and deep-setting separation.

The first technique uses shallow pans about 50 cm in diameter and 10 cm deep. Holding milk in these pans for 30 hours before skimming does not reduce the butterfat content of skim milk to less than 0.5–0.6% (Hunziker, 1927). Trials at the Debre Berhan dairy with locally available shallow pans gave comparable results.

With the deep-setting technique, milk (preferably fresh) is poured into cans approximately 30 cm in diameter and 70 cm deep and held for a period of 24 hours. This reduces the butterfat content of skim milk to 0.3–0.4%, and no further reductions can be obtained by holding the milk for longer periods (Jennes and Patton, 1959). The skim milk is drawn off through a tap at the base of the can.

Centrifugal separation involves simple but relatively costly machinery which gives excellent separation of cream, leaving only about 0.1% butterfat in the skim milk. However, the small quantities of milk (0.5 –4 litres/day) handled by the traditional Ethiopian producer make the use of the separator on individual farms uneconomic. A cooperative arrangement within a Dairy Producers' Cooperative, or among neighbouring farmers, would allow for more economic use of the machine.

A simple economic analysis of centrifugal separation, assuming a return to the primary producer of EB 9 (US$ 4.5) per kilogram of butter, suggests that the extra quantity of butterfat recovered through centrifugal separation over that obtained by gravitational separation would yield an additional EB 5.6 (US$ 2.8) per 100 kg of milk processed. Assuming that the cost of a centrifugal cream separator is EB 1000 (US$ 500), and the interest on the loan plus

maintenance costs over 5 years is EB 230 per year (US$ 115), then the break-even point is 230/0.056, or 4107 litres of milk per year. This is approximately 12 litres/day, so for a single large producer, or a group of farmers, the technique could be economically viable.

Conclusions

The modified earthenware churn has considerable advantages over the traditional churn. The innovation is simple, cheap and effective: the trials reported in this paper indicate that as much as 90% of the fat can be recovered from whole sour milk with considerably shorter churning time and with less labour input than with traditional methods. The improved technology could thus lead to useful increases in the incomes of smallholders.

Gravitational separation of cream also increases fat recovery and reduces churning times. However, the volumes of milk handled daily on the typical highland farm are so small (0.5–4 litres) that no appreciable benefits could be gained by introducing this method. The combined fat losses in the skim milk and the residual buttermilk would probably be just as high (about 10%) as the fat losses in the buttermilk remaining after churning whole milk. Centrifugal cream separation would be economically justifiable only if larger volumes of milk (over 12 litres/day) were available for processing.

Trials to test cream churning demonstrated that the improved earthenware churn is capable of churning cream exhaustively in about 60 minutes. Combining centrifugal separation with the improved churn should ensure profitable processing of quantities of milk of the order of 100 litres/day. Larger volumes of milk would require a wooden churn in addition to cream separation.

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Economic implications of the beef pricing policy in Zimbabwe

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Summary

THIS ARTICLE *outlines the current beef price structure in Zimbabwe, as affected by government interventions, and attempts to estimate the quantitative response of domestic producers and consumers to changes in beef prices. A brief overview of the country's livestock and beef production sectors is given, the trends in beef consumption and the nature of the government pricing policy towards domestic producers are discussed, and initial estimates made of the aggregate demand for beef. The producers' price structure is analysed vis-à-vis world prices, and aggregate supply response parameters, international price transmission relationships, and the beef grading scheme used by the CSC are discussed.*

Introduction

Prices guide producers and consumers in allocating their resources, the most common objectives being to maximise profits and consumption preferences, respectively.

However, price adjustments are seldom free from government interference. The main reasons behind the active involvement of governments in the pricing process are:

- Equity considerations (e.g. since incomes are not usually distributed equally among consumers, the ability of low-income families to purchase a particular commodity will be curtailed if prices increase within a *laissez-faire* environment);
- Lumpiness' of costs or benefits of a particular economic enterprise (e.g. it is difficult to put a value on the benefits of pollution control within the market process because they do not accrue directly to a single individual or entity);
- Protection of the domestic economy against severe fluctuations on the international markets; and
- Political considerations (e.g. lobby groups often put pressure on governments to maintain a particular pricing policy in order to preserve their vested interests).

Governments participate directly in the pricing process by granting subsidies to producers or consumers for certain commodities, by imposing import tariffs or quotas and domestic sales taxes, and by establishing regulatory government bodies such as agricultural marketing boards.

In Zimbabwe, active government involvement in beef pricing policy dates back to 1927, when a surplus of cattle in the domestic market prompted the government to enter into an export agreement with Imperial Cold Storage of Cape Town. The domestic counterpart in this contract was the Rhodesian Cold Storage and Supply Ltd, which was a private company. The 1927 export agreement included two important provisions: it provided a government subsidy to the Rhodesian company and it gave the government the right to expropriate the company after 10 years.

The government took over management and ownership of Rhodesian Cold Storage and Supply Ltd in 1937. The company became known as the Cold Storage Commission (CSC) and established slaughter and cold store plants in Salisbury (1943), Umtali (1946), Fort Victoria (1951), Gatooma (1970), Marandellas (1975), Sinoia (1976), Que Que (1946) and Gwelo (1947). The cold stores in Que Que and Gwelo were relatively small but a major cold store complex was built in Gwelo in 1976.

The objectives of the CSC were to attain self-sufficiency in beef products and to generate foreign exchange earnings from the beef sector.

In 1967, the CSC was placed under the Agricultural Marketing Authority (AMA). The AMA conducts initial hearings with farmers' associations with respect to determining beef producer price levels.

The CSC monitors and controls domestic beef prices in Zimbabwe. The producers' prices are set by the Commission on the basis of production costs incurred within alternative commercial beef production systems. The cost data are supplied partly by the Commercial Farmers' Union (CFU) and partly by the Ministry of Agriculture. Both sources rely on case studies of farming units to generate their statistics on the cost of production.

The consumer price is normally set below the domestic producer price. As a result, the CSC has substantial trade deficits which are financed by the government.

The first section of this article gives an outline of the livestock and beef production structure in Zimbabwe. The second section presents trends in beef consumption, initial estimates of aggregate demand for beef, and the nature of the government's pricing policy towards domestic consumers. The third section gives the producers' price structure *vis à vis* the world market, aggregate supply response parameters, international price transmission relationships and a discussion of the beef grading scheme.

The Zimbabwe livestock sector

The livestock sector in Zimbabwe has always played a vital role in the economy, providing food, generating export earnings or as a major source of domestic farm income, and providing employment. Between 1965 and 1982 livestock products, particularly beef and dairy products, accounted for 17 to 31 % of the total value of primary production in the large-scale commercial livestock sector.

Livestock products are produced on large- and small-scale commercial farms and on peasant holdings in communal areas. The Central Statistical Office (CSO) defines a large-scale commercial unit as one having:

- Five or more permanent employees; or
- Twenty-five or more hectares under crops; or
- Three hundred and fifty head or more of livestock (cattle, sheep, goats and pigs).

Both large- and small-scale commercial units use modern farm technologies. Smallholders use less sophisticated technologies and consume a large proportion of their produce on the farm. Labour on smallholdings is usually supplied by family members.

A significant difference also exists between the numbers of small ruminant stock held in commercial farming areas and on communal lands. CSO statistics indicate that the number of goats. in the communal areas increased from 579 000 head in 1964 to 1 013 000 head in 1983, while the number of goats held on commercial farms fell from 76 000 head in 1970 to 29 000 in 1983.

The number of cattle held on large farms increased between 1920–30 and 1965–77 (Table 1).

Table 1. *Increase in cattle population on large-scale commercial farms, 1920–30 to 1977–81*.

Period	Annual increase (%)
1920–30	1.5
1935–40	2.2
1945–55	2.2
1955–65	2.7
1965–77	5.0
1977–81	–7.2

Source: CSO.

The marked decline between 1977 and 1981 can be attributed to the drought in 1979 and the worsening security situation in the country. The herds in communal areas increased by 5.2% per annum during the period 1965–77 but showed an aggregate decline of 4% per annum between 1977 and 1981.

According to CSO data (AMA, 1983) the number of beef cattle on large-scale farms increased by 1.5% per annum during the period 1966–83. A large part of this increase can be attributed to the increase of 3.62% per annum in the average herd size per farm (i.e. from 358 to 655 head). Over the same period the number of beef farms declined by 2.01% per annum (from 4379 to 3070). The majority of the beef herd of the large-scale sector is in the Matabeleland, North and South Mashonaland and in the Midlands area. In 1983 86% of the country's total beef stock was in these areas.

The changes in the herd structure of the large-scale sector between 1965 and 1983 are shown in Table 2.

Table 2. *Profile of the large-scale sector: Herd inventory, 1965 and 1983*.

Animal category	No. of animals ('000 head)		Annual increase (%)
	1965	1983	
Calves	253	428	3
Breeding females	579	760	1.5
Other females	219	330	2.3
Bulls	25	40	2.6
Other males	443	453	0.1

Source: CSO data quoted in AMA (1983).

Although not shown in Table 2, there was a sharp decline in the number of breeding females in the herds from 1 028 000 head in 1976 to 733 000 in 1980 (AMA, 1983), to which both drought and internal security disruptions contributed.

Between 1964/65 and 1982/83 the average slaughter rate for the large-scale sector was 14% (SD 4%) (AMA, 1983). In the case of small-scale farms, slaughter rates were in the range of 10 to 15% between 1974 and 1978. On the large-scale farms the average annual mortality rate was 3% over the same period, while the annual average calving rate was 58% (SD 6%) between 1965 and 1983.

Most slaughtering of mature cattle is done by the CSC. In 1983, for example, the CSC accounted for 87% of the total number of slaughterings, averaging 82% (SD 5%) over the 1965–83 period. The balance of mature cattle slaughterings is done in CSC-licensed butcheries and on farms.

Beef consumption

Beef consumption increased from 48 050 tonnes in 1965 to 111 300 tonnes in 1983, an annual increase of 7% . Time-series data on aggregate beef consumption are derived from aggregate food balance sheets calculated by the CSO. In 1983 70% of the meat consumed in Zimbabwe was beef. Consumption of pig and poultry meat, which are possible substitutes for beef, increased by 3% and 9% per annum, respectively, from 1970 to 1982. Although consumption of poultry meat increased faster than beef (9 vs 7% per annum) during this period, poultry meat accounted for only 10% of the total meat consumption in 1983.

The terms of trade (ratio of the retail price of the substitute to the retail price of beef) seem to be in favour of beef consumption, as indicated by the data in Table 3.

Table 3. *Terms of trade for major meat products in the Harare area, 1973–80*.

Year	Mutton/beef	Pork/beef	Chicken/beef
1973	2.06	1.80	1.46
1974	2.05	1.70	1.43
1975	1.94	1.64	1.39
1976	2.75	1.76	1.30
1977	2.59	1.67	1.29
1978	2.43	1.58	1.47
1979	2.29	1.73	1.40
1980	2.55	1.82	1.60

Source: CSO data quoted in AMA (1983).

Favourable terms of trade for beef reduce demand for the substitute products. It is difficult, however, to assess whether it is government policy to preserve a large share of the domestic meat market for beef producers, since only the retail price of mutton is not subject to government price control. On the other hand, part of the reason for the higher prices of pork and chicken relative to beef could be their higher feed costs.

Domestic budgetary subsidies allotted to the beef sector comprise a substantial proportion of the total agricultural subsidy (Table 4).

Table 4. *Subsidies to the beef sector and total subsidy for the agricultural sector, Zimbabwe, 1976/77–1981/82*.

Year	Beef subsidy (Zimbabwe $'000)	Total agricultural subsidy (Zimbabwe $'000)
1976/77	6 338	9 458
1977/78	11 265	14 483
1978/79	20 516	42 173
1979/80	12 920	26 302
1980/81	9 619	50 568
1981/82	25 730	121 650

Source: Jansen (1982).

To examine the economic aspects of the beef subsidy, the domestic retail price for beef was compared with the border price equivalent of beef (i.e. CIF beef import price). If the domestic retail price is above (below) the border price, consumers face implicit taxes (subsidies). The basic data used in calculating the domestic retail price for beef and CIF beef import price was obtained from the CSC and AMA. The estimated price ratios are given in Table 5.

Table 5. *Average domestic retail price/border price ratios for beef, Zimbabwe, 1966–69 to 1976–81*.

Period	Retail/border price ratio
1966–69	0.72
1970–72	0.95
1973–75	0.75
1976–81	1.16

As can be seen in Table 5, domestic beef consumption was subsidised until 1975, while in 1976–81 the consumer was taxed. However, despite the insight into government policy regarding domestic consumer prices provided by the data in Table 5, use of these price ratios should be treated with caution. Firstly, the degree of under- or over-valuation of the exchange rate has not been considered. If the exchange rate is over-valued, the ratio will be over-stated to the same degree. Secondly, the marketing margin of 35% used to adjust the border price to the equivalent domestic level is largely determined by the CSC and may include either some monopoly profits or additional costs arising from possible marketing inefficiencies.

Aggregate domestic demand for beef was estimated for the period 1970–83. In linear and log form (base e), the relationships are:

$$(1)\quad q_{bt} = 17.46 - 0.17_{bt} - 0.26D_R$$
$$\text{a.}\quad (0.61$$
$$R^2 = 0.27\ DW = 1.71$$

$$(2)\quad \log q_{bt} = 4.16 - 0.48 \log P_{bt} - 0.02D_R$$
$$\text{a.}\quad (0.05)$$
$$R^2 = 0.25\ DW = 1.62$$

where: q_{bt}, is the per caput beef consumption in period t.

P_{bt} is the domestic retail price of beef in period t divided by a cost of living index.
D_R is a binary variable equal to 1 in the presence of a rationing scheme and 0 otherwise.
DW is the Durbin–Watson test.

Numbers in parentheses in all regression equations reported in this article are standard errors of the corresponding regression coefficient, and all R^2s have been adjusted for degrees of freedom.

The fit of expressions (1) and (2) is not satisfactory. However, the price coefficients are statistically significant (as indicated by the t-value being approximately equal to 2), and the price coefficient in both expressions has the correct sign. Serial correlation problems are not serious since the Durbin-Watson values are close to 2.

However, since the null hypothesis for testing the significance of an individual regression coefficient is that it equals zero, it is not necessarily relevant to look at the levels of significance

of the price coefficients of demand relationships. Hence, in order to evaluate the statistical dispersion dimensions of the elasticity estimates generated by (1) and (2), the 95% confidence interval for the elasticity parameters was estimated. In the case of the linear form, wherein the price elasticity was estimated at the means, the method of Fieller (1944) was used to compute the confidence interval.

The 95% confidence intervals of the price elasticity coefficient in absolute terms for (1) and (2), respectively, are:

(a) $0.35 < 0.51 < 0.72$
(b) $0.36 < 0.48 < 1.33$

Ideally, the ‘best' confidence interval is the one with the narrowest range of values. In this regard, the elasticity estimate of the linear function is superior to that of the log form.

The price elasticities mean that a 10% increase in the retail price of beef will induce a 5% reduction in per caput beef consumption. Conversely, a small change in per caput beef consumption will induce a larger change in the price of beef.

Also, since the demand relationships are price inelastic (i.e. less than 1 in absolute terms), an increase in the price of beef will increase the proportion of consumers' budgets that is spent on beef. Since high-income groups spend almost twice as much on beef as do low-income groups, any increase in beef price by the government would be resisted by the former group. This probably explains why prices were subsidised until 1975, i.e. the high-income consumer group wielded substantial political power up to 1975.

Exports comprised 44 to 68% of total beef sales between 1965 and 1979. Exports of beef (both frozen and canned) comprised 50 to 93% of the total value of meat products exported between 1970 and 1981. Prior to 1978, most of the exports were destined for South Africa. By 1980, beef exports had declined sharply. Political instability in 1977–79 led to the deterioration of veterinary field services and destruction of dipping facilities. This resulted in a significant reduction in the domestic supply of beef, and less beef of export quality being available. As a result, beef was rationed during the period 1979–1981.

Pricing policy towards beef producers

As shown earlier, the CSC is the main body controlling prices paid to domestic beef producers. Most cattle are slaughtered by the CSC, and the CSC's carcass grading scheme is the basis for payments to producers. In general, pricing cattle on the basis of carcass and grade has the following advantages:

- Pricing can be based on the characteristics of the animal. As such, consumers (both domestic and foreign) are assured of a wide variety of easily identifiable beef products of different qualities with corresponding prices.
- It eliminates marketing costs which could arise from differences in the information that is available to the producer and marketing agent. Selling livestock on a liveweight basis involves a lot of information on the animals' traits that can be known only to the producer or the marketing agent at the time of purchase. This information is usually measured

subjectively and generated through familiarity of the producer or marketing agent with the animals concerned.

A carcass grading system must be accurate, objective and feasible. To meet the first two criteria, the CSC introduced a grading system in July 1977 under which carcasses were grouped according to age, flesh development (based on length to weight ratios), and fat cover. Prices paid were based on the various quality combinations.

However, despite the detailed quality specifications embodied in the 1977 document, there were still some grey areas within the grading policy. Van Vliet (1982), using the 1981/82 price schedule, illustrated that the price difference between two similar carcasses could be as much as 44%. As a result, the flesh-class component of the 1981/ 82 pricing schedule was further subdivided into very narrow intervals to minimise ambiguity with respect to such quality.

While it is accepted that the carcass grading policy will impose a price penalty on poor-quality beef cattle, it will favour commercial beef producers since they have the resources to be able to adopt the technology needed to produce good-quality cattle.

A government pricing policy aimed at generating surpluses for export in the long run will be targeted at the farm sector that is most sensitive to price changes. To examine this an empirical analysis of the response to changes in supply price was undertaken for the commercial and communal farm sectors in Zimbabwe.

The beef supply relationship for commercial producers was estimated through an Almon model (a finite expectation relationship) since it gave better fit and statistical significance of regression coefficients than the alternative lag models considered (e.g. Fisher, Koyck, Pascal). An end-point constraint was imposed to set a terminal point for the impact of the price variables.

The empirical estimate of the Almon lag model is:

$$(3) \qquad \hat{S}_t = 347.07 - 11.92V_{t1} + 3.09V_{t2} + 40.76t$$
$$\qquad\qquad\qquad\qquad (3.82) \qquad (1.08) \qquad (8.05)$$

$R^2 = 0.75$ DW $= 1.71$

where: The sample size is 17.

$\hat{S}_t$ is the slaughter level (in thousand head).

$$V_{t1} = \sum_{T=0}^{3} (T-3)\,P_t - T$$

$$V_{t2} = \sum_{T=0}^{3} (T-9)\,P_{t-T}$$

P_{t-T} is the price variable.

t is the time variable.

To detect the presence of collinearity among the independent variables in equation (3), Eigenvalues corresponding to orthogonally transformed vectors of V_{t1}, V_{t2} and t were computed. As an operational rule, an Eigenvalue between 0.1 and 0.3 indicates moderate multicollinearity;

a value of less than 0.1 indicates high multicollinearity. The Eigenvalues corresponding to C' (V_{t1}, V_{t2}, t)' (V_{t1}, V_{t2}, t) C (where C is an orthogonal vector) are 2.87, 0.004, and 0.13. Multicollinearity is generated by the inclusion of V_{t2} in equation (3). To minimise the degree of multicollinearity and specification errors, ridge regression was used to re-estimate equation (3). Ridge regression gives biased regression coefficients but efficient estimators. Details of the ridge methodology are given in Rodriguez (1984). A ridge estimate of equation (3) at the ridge scalar of 0.0001 is:

$$(4)\ \hat{S}_t = 373.16 - 9.07V_{t1} + 2.28V_{t2} + 41.22t$$

The ridge estimation process reduced the sum of the variance inflation factors of the regression parameters by 77% .

The price elasticities were derived from equations (3) and (4) by re-expressing V_{t1} and V_{t2} in terms of the original price variables. The resulting price elasticity estimated at the means ranged from –0.49 to –0.61. In terms of sign, the elasticities obtained are consistent with economic theory, since if producers expect prices to increase they will hold back animals from slaughter because they need a larger herd to increase their slaughter offtake levels. The absolute magnitudes of the elasticities are comparable to those obtained elsewhere, e.g. Brazil (–0.113 to –0.575); Argentina (–0.668 to –0.962); and Colombia (–0.058 to –1.20).

For communal farmers, the empirical beef supply function is: (5) log M_t equals

$$\underset{}{7.37} - \underset{(0.21)}{0.34 \log P_{t-1}} + \underset{(0.12)}{0.41 \log M_{t-1}} + \underset{(0.11)}{0 \cdot 10 \log t} + \underset{(0.10)}{0.25D} - \underset{(0.16)}{0.97W}$$

$$R^2 = 0.90 \quad DW = 2.05$$

where: The log transformation is to the base e.

M is the total number of cattle sold at official auctions in the communal farming areas in period t.
D is a binary variable representing the presence of drought conditions (equal to 1 for the years 1968, 1970, 1979, 1982 and 1983, and 0 otherwise).
W is a binary variable for the internal security situation (equal to 1 for the years 1978 and 1979 and 0 otherwise).

The period of fit for equation (5) is 1965–83. The equation is the reduced form of the logarithmic Koyck lag model. This framework assumes that weights attached to prices by communal farmers decline geometrically with the age of the price information. Equation (5) gives acceptable statistical values of R2, DW, and standard errors of the regression coefficients.

Equation (5) gives a short-run price elasticity of –0.34, which is much lower than that obtained for commercial farmers and lower than previous estimates of –1.05 in Swaziland (Doran et al, 1979) and 1.10 to 1.15 in Sudan (Khalifa and Simpson, 1972). The estimates for Sudan and Swaziland are extremely high because the endogenous variable used in their supply

relationships is not a pure representation of sales of beef from peasant farms but also includes sales of commercial private farmers and beef sales at premium markets.

Nevertheless, if the response of the commercial producers to a price change is 44 to 79% larger than that of communal farmers, then any factor in the government's price policy that encourages increased production will be in favour of commercial farmers.

The supply price elasticities estimated for the Zimbabwe domestic beef producers also have the following implications:

- In the short run, an increase in the price paid to domestic producers will result in fewer animals being slaughtered. Coupled with increasing demand for beef, this will result in a smaller surplus of beef for export which would reduce the foreign exchange earnings of the beef sector in the short run.
- A higher producer price will induce an increase in cattle inventories. Larger numbers of cattle will require an increase in the usage of domestic resources such as land, labour, coarse grains, etc. If the increase in the cattle activity reduces resources available to crop activities in which Zimbabwe enjoys a comparative advantage, then the producer price will incur an efficiency cost. On the other hand, if the increase in the cattle population increases consumption of crop byproducts which have zero opportunity costs, then some indirect benefits will be realized.

An index which can be used to monitor the ex-post impact of a given price policy is the nominal protection coefficient (NPC):

(6) $NPC = P_d/P_w$

where: P_d is the domestic producer price.

P_w is the border price.

In the case of beef, the border price is defined as:

(7) $P_w. = rP_X – N + R$

where: r is the nominal exchange rate.

P_x is the border price in foreign currency per kg.
N is the marketing margin.
R is the revenue from cattle byproducts.

If the NPC is greater or less than 1, then the domestic producer is subsidised or taxed.

The nominal rates of protection for beef are given in Table 6.

Table 6. *Nominal rate of protection of the beef sector in Zimbabwe, 1965–69 to 1975–82*.

Assumptions	1965–69	1970–74	1975–82
NPC1	1.14(0.08)	1.25(0.10)	1.64(0.20)
NPC2	0.98(0.06)	1.07(0.09)	1.40(0.16)
NPC3	0.91(0.06)	1.00(0.08)	1.32(0.16)
NPC4	0.85 (0.06)	0.92 (0.07)	1.22 (0.15)

Notes:
1. The assumed marketing margins are 40% (NPC1) and 30% (NPC2, NPC3, NPC4).
2. The assumed proportions of revenue contribution from offals and hides are 25% (NPC1 and NPC2); 30% (NPC3); and 35% (NPC4).

The NPC was averaged for each of the three subperiods. It was also estimated under various marketing margins and proportions of revenue from byproducts. Comparison of the various NPCs under varying assumptions with respect to N and R indicates:

- Increasing N by 25% increases NPC by 17%.
- Increasing R by 17% leads to NPC being understated by 8% .

It is evident from Table 6 that beef producers in Zimbabwe were increasingly subsidised from 1965 to 1982. If estimates that subsidies on beef consumption are declining are correct, then the trend in the NPCs implies that the government is trying to increase rural incomes (mostly of commercial farmers) at the expense of urban beef consumers.

This paper also examines the extent to which the government's beef pricing policy in Zimbabwe allows the domestic beef market to be exposed to international market conditions. If the government does not insulate the domestic market from price changes on the international market, then the international beef price cycles would be experienced by domestic beef producers. In other words, in periods of high international beef prices, the number of animals slaughtered by domestic producers would decline, resulting in fewer exports of beef from Zimbabwe.

The degree to which the Zimbabwe beef market is insulated from the international market was examined using equation (8):

$$(8)\quad \dot{P}^{d} = a + b\,\dot{P}^{w}$$

where: $\dot{P}^{d}$ is the expected domestic producer price.

$\dot{P}^{w}$ is the expected world price

If b = 0, livestock producers' prices are completely insulated from changes in the international market price of beef. It can also be proven that as b approaches 0, substantial variations in the NPC occur. This results in variations in the implicit subsidies to or taxes on domestic beef

producers. Substantial changes in the price incentive structure confronting domestic beef producers will induce variations in production (an ‘unwelcome' instability).

The empirical estimate of equation (8) for the period 1965–82 is:

(9) $P_d^* = 15.64 + 0.77P_w^* - 1.02t$

(0.12) (0.57)

$R^2 = 0.89$ DW = 1.28

where: P_d and P_w are in cents per kg of ‘bone-in' beef of average quality.

The fit for (9) is reasonable, as indicated by the R^2. There was no significant autocorrelation at the 5% level. The coefficient of Pw*, is also statistically significant with its t-value (6.41) being greater than 2. Thus, the magnitudes of the coefficients in equation (9) (when b 0) indicate that the government permits the price paid to domestic producers to respond to changes in international market conditions.

Summary and conclusions

Governments intervene in the pricing process in an economy for a number of reasons, including externalities, equity considerations and political pressure from lobby groups, which are closely related to one another. The price policies are effected through subsidies, tariffs, government-owned bodies, and economic licensing requirements.

In Zimbabwe, government pricing policy in the beef sector is implemented through the CSC. The government's pricing policies since the 1920s have been oriented towards attaining self-sufficiency in beef production and realizing beef export earnings.

The objectives of this study were to describe the price structure resulting from the government's intervention and to quantify the response of domestic beef producers and consumers to changes in beef prices.

The major empirical findings are that:

- The government's pricing policy tends to be producer-oriented, as indicated by the trend of increasing nominal protection coefficients for the period 1965–82 coupled with the pattern of declining subsidies to domestic beef consumers from 1966 to 1975 and the subsequent taxation of domestic beef consumption from 1976 to 1981. The latter fact reflects the decline of the political influence of the high-income urban dwellers.
- The absolute magnitude of the supply price elasticity parameter for commercial beef producers is 44 to 79% higher than that obtained for communal farmers. Hence, if the objective of the pricing policy is to generate a surplus of beef for export, then the corresponding benefits arising from this will accrue largely to commercial beef producers.,

- The domestic demand for beef is price inelastic (with a value of –0.48 to –0.51*).* This implies that a slight change in per caput consumption of beef will exert pressures on the government to permit a more than proportionate change in the retail price of beef.

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Kanwa cattle salt as a potential micronutrient fertilizer in Nigeria's Middle Belt

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Summary

UNTIL RECENTLY kanwa *has primarily been known as a mineral supplement fed to traditionally managed cattle in central and northern Nigeria. Preliminary studies carried out by ILCA's Subhumid Zone Programme in 1984 indicated its potential as an economically attractive source of plant micronutrients. A 200 kg/ha increase in the crude protein yield of stylo (*Stylosanthes hamata *cv. Verano) was obtained by applying 50 kg of* kanwa *per ha, at a total cost of only US$ 5.00.*

Introduction

With an average rainfall of 900–1500 mm per annum, the subhumid zone of Nigeria could, with favourable soil conditions, support high levels of plant production. However, even when NPK fertilizer is applied crop yields are usually low, which is largely attributed to micronutrient deficiencies (Heathcote, 1970; Osiname et al, 1973; Smithson and Heathcote, 1974).

ILCA's studies on *Stylosanthes hamata* cv. Verano at the Kachia Grazing Reserve, Kaduna State, Nigeria, showed that this forage legume has high resistance to anthracnose and recovers well after being burned or overgrazed. However, its dry-matter (DM) yields were disappointing and its response to phosphorus (P) was less than expected.

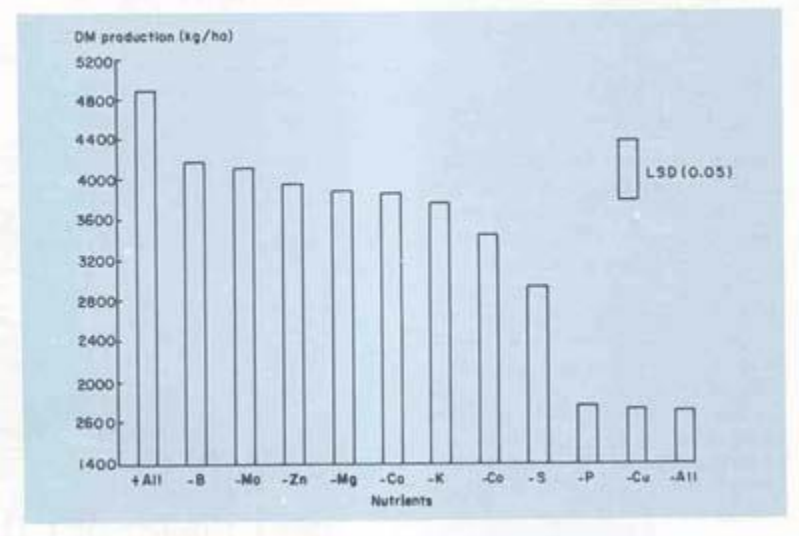
Concurrent with these studies, livestock nutrition studies were conducted in an effort to explain a dry-season flush of oestrous activity in cows supplemented with *kanwa,* a traditional cattle salt containing essential micronutrients. The possible use of this relatively cheap material as a micronutrient fertilizer was examined and the results are reported in this article.

Methods

Micronutrient deficiencies

In 1983, a series of nutrient omission experiments were conducted to determine the cause of the lower-than-expected DM yields of *Stylosanthes hamata* cv. Verano. Figure 1 shows DM production of*S. hamata* when supplied with all essential nutrients and when systematically deprived of individual nutrients. The results clearly indicate that P and copper (Cu) were the most limiting nutrients: when either was withheld the yield was as low as when no nutrients were applied.

Figure 1. *Dry-matter production of* S. hamata *supplied with all nutrients and systematically deprived of individual nutrients, Kurmin Biri, 1984.*



Fertilizers to correct specific micronutrient deficiencies are not available in Nigeria. The commonly used commercial NPK fertilizers contain varying amounts of micronutrients as impurities, but in quantities which are generally insufficient to correct severe deficiencies.

An analysis of *kanwa* carried out as part of the Programme's livestock nutrition studies revealed that it contains many essential micronutrients, including Cu (Table 1). This finding attracted interest in the possible use of *kanwa* as a cheap micronutrient fertilizer. *Kanwa* is mined in northeastern Nigeria and costs between 8 and 10 (US$ 10–12.5) per 100 kg.

Table 1. *Composition of* kanwa.

Element	Content
Major nutrient (%)	
Na	1.5
K	4.7
Ca	23.7
P	0.6
Micronutrient (ppm)	
Mg	848.7
Fe	74.7
Mn	407.2
Cu	44.2
Co	23.6
Zn	176.0

Kanwa as a micronutrient fertilizer

In 1984 a trial was conducted at the Kachia Grazing Reserve on ferruginous soil, on the use of *kanwa* as a micronutrient fertilizer. The area used for the experiment had been under *S*. *hamata* since 1980.

Thirty-six 1 m^2 plots separated by 0.3 m wide paths were laid out in a 3 x 4 factorial design with three replicates. The treatments were 0, 50 and 100 kg of *kanwa*/ha (KW_0, KW_1 and KW_2) and 0, 18, 36 and 54 kg P/ha (P_0, P_1, P_2 and P_3). The *S*. *hamata,* which was about 8 cm high at the start of the experiments, had also received 12 kg P/ha at the time of establishment.

The *kanwa* and triple superphosphate were mixed and topdressed in the second week of June 1984. The plots were harvested in early November, and DM and seed yields of the stylo were determined.

Results and discussion

Application of either *kanwa* or P significantly ($P < 0.001$) increased the DM yield of *S*. *hamata* (Figure 2). The response to *kanwa* was linear up to the highest level of application (100 kg/ha) while the response to P was quadratic with maximum DM yield occurring at 36 kg P/ha (Table 2). Application of P and *kanwa* also significantly ($P < 0.001$) increased seed yield of *S. hamata* (Figure 3).

Figure 2. *Experimental plots showing the effect of P and* kanwa *on* S. hamata *cv Verano.*

Photo: Ann Waters-Bayer.

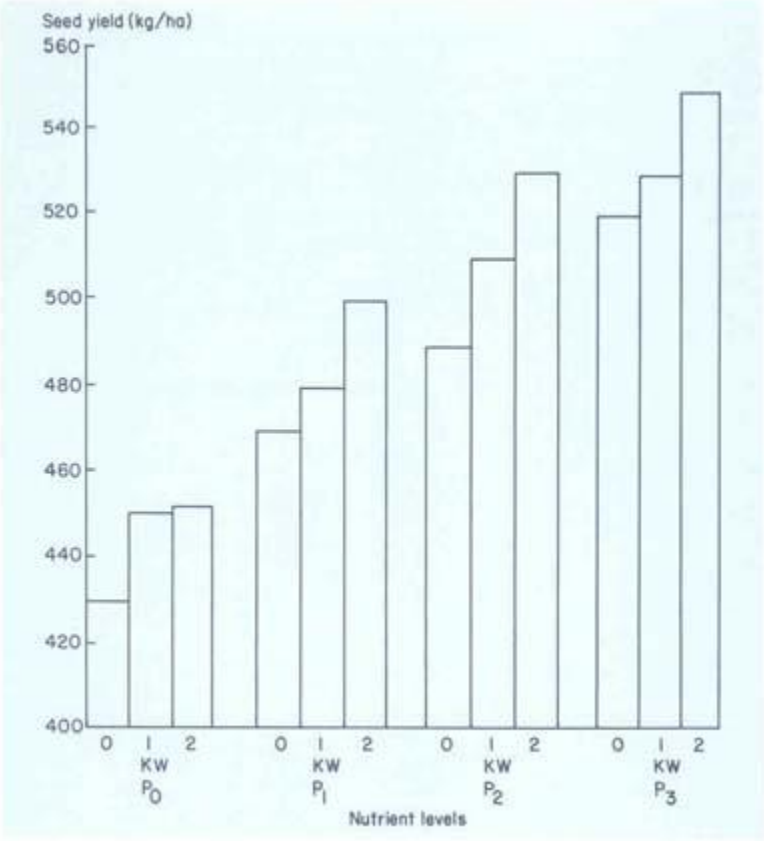
(P_0Kw_0 = Zero levels of P and kanwa).

Table 2. *Effect of P and* kanwa *applications on dry-matter production of* Stylosanthes hamata *cv. Verano, 1984*.

Phosphorus rate (kg/ha)	DM yield of *S. hamata* c. Verano (kg/ha)			
	Kanwa rate (kg/ha)			Mean
	0	50	100	
0	2936±252*	4 412	4 828	4 059±146*
18	4 864	5 048	5 636	5 182
36	4 544	5 884	6 484	5 637
54	4 964	5 360	6 484	5 603
Mean	4 327±126*	5 176	5 858	

* ± SE (Standard error).

Figure 3. *Effect of P and* kanwa *applications on seed production of* S. hamata, *Kurmin Biri, 1984.*



An analysis of crude protein (CP) yield revealed that applying 50 kg of *kanwa/*ha (at a cost of ₦ 4 or US$ 5) increased the CP yield of *S. hamata* by 200 kg/ha. Two hundred kilograms of CP in the form of cottonseed cake, which is the most readily available alternative source of CP, would cost about US$ 230.

Increasing population pressure in the subhumid zone of Nigeria has resulted in arable agriculture expanding onto less fertile land, where crop–livestock production is more difficult to sustain due to rapid soil degradation.

Trials by ILCA have shown that growing *Stylosanthes* for 1–3 years can substantially improve soil structure and fertility (Mohamed-Saleem, 1984), and that these improvements are positively correlated with the amount of stylo biomass produced. Hence if yields of stylo can be increased by using a combination of P fertilizer and *kanwa,* the yields of subsequent food crops should be substantially increased, at lower cost than with commercial N fertilizers.

The increase in stylo yield when *kanwa* was applied may be partially due to nutrients other than P and Cu, and *kanwa* may be useful as a broad-spectrum micronutrient fertilizer. However, before*kanwa* can be used as fertilizer on a wide scale, it will be necessary to ascertain:

- The extent and the type of micronutrient deficiencies in the subhumid zone;
- Optimum levels of *kanwa* application;
- The extent of *kanwa* deposits available; and
- The economics of its complementary use as a direct livestock mineral supplement.

Conclusions

The results reported in this paper demonstrate the potential of *kanwa* to correct the micronutrient deficiencies of ferruginous soils, which constitute more than 50% of the soils in the subhumid zone. A combination of forage legumes, which can fix atmospheric N at low levels of P application, and *kanwa* will greatly improve soil fertility, thereby increasing production of food crops and providing better-quality forage.

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List of abbreviations

AMA	Agricultural Marketing Authority (Zimbabwe)
AOAC	Association of Official Analytical Chemists (USA)
ARE	agricultural research expenditures
CGIAR	Consultative Group on International Agricultural Research (Washington D.C.)
CIF	carriage, insurance and freight
CSC	Cold Storage Commission (Zimbabwe)
CSO	Central Statistical Office (Zimbabwe)
CT	Churning time
Cu	copper
DM	dry matter
EB	Ethiopian Birr
FC	fat content
GDP	gross domestic product
GR	growth rate
IARC	international agricultural research centre
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics (India)
IITA	International Institute of Tropical Agriculture (Nigeria)
ILRAD	International Laboratory for Research on Animal Diseases (Kenya)
kg	kilogram
KW	kanwa cattle salt
ml	millilitre
₦	Naira
N	nitrogen
NPC	nominal protection coefficient
P	phosphorus
SE	standard error
TLU	tropical livestock unit (250 kg LW)